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Short Communication

Influence of Temperature and Relative Humidity on the Performance of Nitrogen Dioxide Diffusive Sampler

Šerevičienė V. and Paliulis D.
Department of Environment Protection, Vilnius Gediminas Technical University, Vilnius, LITHUANIA

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Abstract

Passive diffusive samplers provide an excellent opportunity to perform indicative measurements or establish a dense network of measuring sites. This paper describe and present the results of experiments in exposure chamber to determine the effects of different ambient air temperature (T) and relatively humidity (RH) on the performances of passive diffusive samplers for measuring nitrogen dioxide (NO_2) in the outdoor environment. In experimental studies were used passive diffusive samplers with stainless steel grids and impregnating solution of 10% (v/v) triethanolamine (TEA) with water. During these researches in laboratory chamber passive samplers was exposed at various conditions: temperature from 10°C to 40°C and relatively humidity from 30% to 80%. During these variations in conditions NO_2 concentration was constant, approximately 40 $\mu g/m^3$. Influence of temperature and relative humidity are weak on passive sampler performance when ambient temperature is 20°C and relatively humidity 60%. Changing environmental conditions (T > 30 °C and RH > 75 %) indicates accuracy of passive samplers 10–35% when compared to co-located continuous NOx analyzer.

Keywords: nitrogen dioxide, diffusive sampling, air monitoring, temperature, relatively humidity, laboratory chamber.

Introduction

Nitrogen dioxide (NO_2) is common combustion related pollutant that is mostly formed from oxidation of nitric oxide (NO) which is produced during high temperature burning of fuel in cars and other road vehicles, heaters and cookers[1–3]. Nitrogen dioxide is considered to be an important atmospheric trace gas pollutant because of its effects on health[4,5].

Generally NOx monitoring is carried out using high volume samplers, handy samplers or through a chemiluminescence analyser. Such instruments require on site power source, apart from being capital intensive, involving complex operations and requiring specialist maintenance. In view of these limitations, extensive air quality monitoring over wide geographical areas presents serious difficulty. Passive samplers provide a convenient alternative for measuring ambient NO_2 in a highly cost effective manner[6–8]. Currently, passive samplers are being used to determine the air quality in the work place, the living environment; and the ambient, outdoor environment including regional-scale air quality[9–11].

The passive sampler is based on the principle of diffusion of air. The atmospheric NO_2 diffuses up the tube where it gets absorbed on the triethanolamine (TEA) coated mesh. This establishes a NO_2 concentration gradient along the length of tube, consequently NO_2 diffuses up the tube where it is absorbed on TEA coated meshes.

Even though passive sampling has been widely used and recognized as a valuable tool in environmental monitoring, the reliability of this technique under varying environmental conditions is always a subject of controversy. Theoretical treatment using Fick's laws of diffusion is based on the assump tion that steady-state conditions apply to passive samplers. In practice, this is not true, since the actual uptake of the analytes varies depending on factors like temperature and concentration, which define the two constants: diffusion coefficient in the case of diffusive samplers and permeability in the case of permeation samplers[12-16].

Environmental factors, such as temperature, relatively humidity, and wind speed can affect the performance of passive samplers[12,13]. Consideration of these environmental factors when selecting a sampler for field studies is important. Sampling rates determined under ideal conditions may not be valid across the varying environmental conditions that occur throughout a tipical sampling range of concentrations, wind velocity, temperature, and relative humidity[6,12,14].

Palmes claimed insignificant influence of temperature on the performance of passive samplers[17]. Other researchers conducted investigation results on the effect of temperature on the performance of passive samplers have shown that each 10◦C rise in temperature enhances 11–18 percent uptake by passive samplers[18]. Recent studies using stainless steel mesh and TEA solution, as an absorbing material, have shown insignificant effect of temperature on sample collection. An increased uptake reported by early studies was probably because of the use of absorbing materials other than that of stainless steel mesh (mainly Whatman filter paper)[19]. Over scientist also observed 25 percent increase in the NO_2 absorbance, when the relative humidity rose from 0 to 100 percent[18]. Humidity is probably the most important environmental variable that affects the performance of passive diffusion samplers using TEA as absorbent, because TEA does not perform quantitatively at low humidities[20]. Although in the use of passive samplers in the field, the effect of humidity is of not much consequence because the relative humidity of the ambient air is usually more than 40 percent.

The aim of these performed researches is to investigate effects of temperature and relatively humidity to performance of diffusive samplers in laboratory chamber.

Material and Methods

The diffusive tube samplers applied in this study consists of the polypropylene tube approximately 34 mm long and 21 mm inner diameter and closely fitting cap. In one end of the diffusive tube is placed one stainless steel mesh (figure 1).

For the preparation of diffusive tubes stainless steel mashes were impregnated with 10 % (v/v) solution of TEA and water. After exposure samplers were analysed in the laboratory spectrophotometrically using Saltzman reagent. Ten minutes are required for full coloured development before optical absorbance of the coloured solution is measured spectrophotometrically at 542 nm. The amount of nitrite ion in the sample is obtained with the help of calibration plot derived from standard nitrite solutions. The amount of extracted nitrite for samplers is used to calculate ambient NO_2 concentrations.

The laboratory experiments were performed in an exposure chamber that allowed controlling of concentrations level, temperature and relative humidity. The exposure chamber size was 1.5 m lengthy, by 1.5 m width and by 1.8 m height with a volume of 4.05 m^3.

The nitrogen oxides in the chamber were obtained by means of the reaction between sulphuric acid and sodium nitrite. During the chemical reaction between sulphuric acid and sodium nitrite there are released nitrogen oxides into the air. 0.1 N sulphuric acid was dripped from burette into the glass with 20% aqueous solution of sodium nitrite to obtain expected NO_2 concentration. During the experiments in the exposure chamber, NO_2 was monitored using a chemiluminescence nitrogen oxides analyzer AC32M which was calibrated using a primary reference gas mixture. Its detectable limit is 0.4 μg/m^3. To accelerate mixing of air in the chamber, the fan was used.

The parameters of microclimate were measured in the chamber during experiment with data logger DrDAQ: temperature and relative humidity. Data were recorded automatically in the computer. The sensors for temperature and relative humidity were placed at the 1 m height, in the same place were diffusive samplers are placed (figure 2).

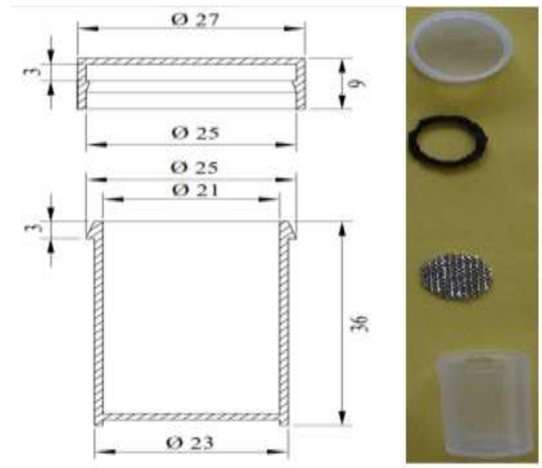


Figure-1
Scheme of passive diffusive sampler

The exposure conditions are chosen to cover a temperature range from 10°C to 40°C and relatively humidity from 30% to 80%. During these variations in conditions NO_2 concentration was constant, approximately 40 μg/m^3. Samplers were exposed for 1 week.

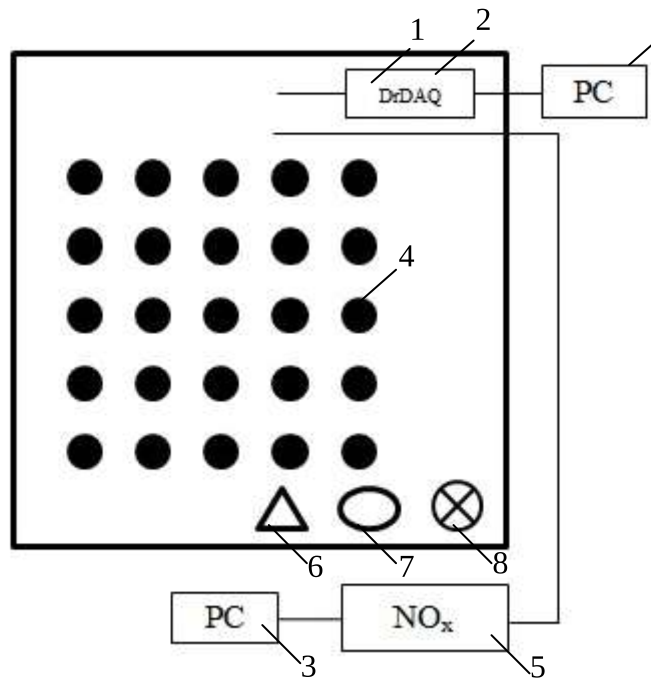
Results and Discussion

Passive diffusive samplers provide an excellent opportunity to perform indicative measurements or establish a dense network of measuring sites. This paper describe and present the results of experiments in exposure chamber to determine the effects of different ambient air temperature (T) and relatively humidity (RH) on the performances of passive diffusive samplers for measuring nitrogen dioxide (NO_2) in the outdoor environment.

During these researches in laboratory chamber passive samplers was exposed at various combined conditions of temperature and relatively humidity to estimate the single effect of each factor and their interaction on the performance of passive diffusive samplers.

Precision is a measure of the variability of response expected at any given concentration or various conditions. The relative standard deviation (RSD, %) is a common indicator of precision. Precision of diffusive samplers with 10% TEA/water impregnating solutions is 5–7%. The accuracy of the passive samplers in comparison to chemiluminescence technique expressed as percent relative error (RE, %).

During chamber experiments individual NO_2 diffusive tubes were generally in very good agreement with chemiluminescence measurements. Influence of temperature and relative humidity are weak on passive sampler performance when ambient temperature is 20°C and relatively humidity 30%, accuracy 5% (figure 3). Worse accuracy (10%) was obtained during experiment when *RH* was 35%.



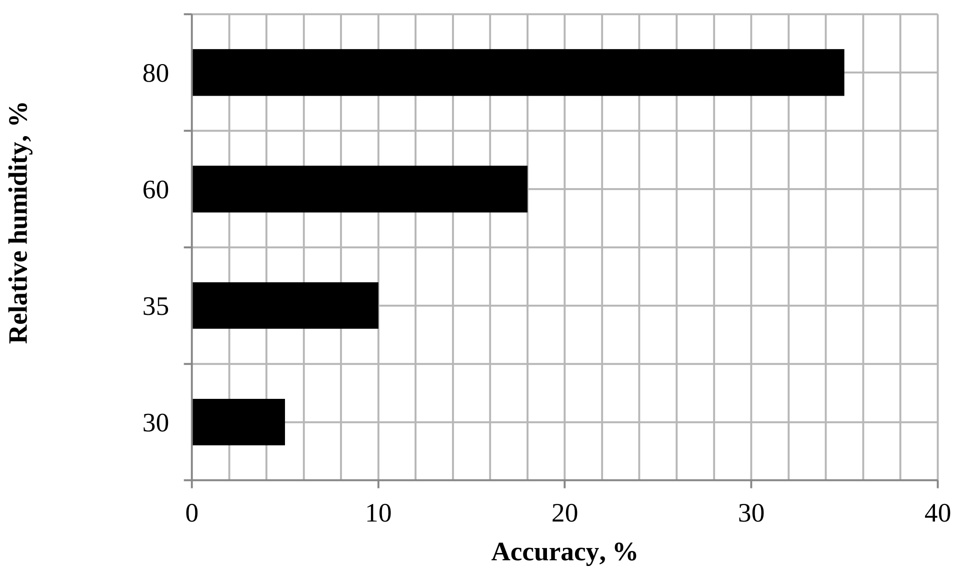


Figure-3
Accuracy of diffusive samplers obtained during experiments at various combined conditions of temperature and relatively humidity

Changing environmental conditions (T > 35 °C and RH > 80%) indicates accuracy of passive samplers 25% when compared to co-located continuous NOx analyser. Both the chemical reaction rate and the diffusion rate in the liquid phase are strongly temperature dependent. Sampling rate of passive diffusive sampler is dependent to ambient temperature, because coefficient of molecular diffusion is temperature dependent. Two explanations are possible for the temperature dependence: either because the temperature modifies the concentration of water vapour that influences the efficiency of NO_2 absorption by TEA, or because Fick's coefficient of diffusion of NO_2 in air by ± 12 % between 20 and 40 °C, and hence the sampling rate as well. High humidity can also alter the sorption behaviour of the exposed inner wall of tube-type samples or draught screen, particularly if condensation occurs [15].

Conclusion

Although passive diffusive samplers are extremely useful for estimating the spatial pollutant concentrations, it is necessary to know the limitations for their adequate use in urban air monitoring. Experiments in exposure chamber are carried out to evaluate the influence of meteorological factors (temperature and relative humidity) on the sampling rate of NO_2 passive diffusive sampler. Humidity is probably the most important environmental variable that affects the performance of passive diffusion samplers using TEA as absorbent. TEA does not perform quantitatively at low humilities.

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